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2 May 1980

USSR Report

CONSTRUCTION AND EQUIPMENT

(FOUO 4/80)

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USSR REPORT

CONSTRUCTION AND EQUIPMENT

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Makarychev Introduction

Moscow STANTKI I INSTRUMENT in Russian No 2, Feb 80 pp 1-2

[Article by Yu. I. Makarychev, deputy representative of the central administration of the Scientific-Technical Society of the Machinebuilding Industry: "Tasks of the Scientific-Technical Society at the Present Level"]

[Text] The Soviet country entered the final year of the Tenth Five-Year Plan period -- the year of active preparation for the 26th congress of the party. The November (1979) Plenum Central Committee of the party defined the problems faced by the national economy today, exposed shortcomings in work and indicated ways for overcoming them. The decree adopted by the Central Committee of the party and the USSR Council of Ministers "On improving planning and strengthening the influence of the economic mechanism on raising the efficiency of production and the quality of work" is a document of vast importance in which concrete measures are outlined for the further development of cost accounting, expanding the rights of working collectives in the distribution of economic incentive funds and for raising the creative activity of the masses. The decree specifies a single system of long-term, five-year and annual plans, the strengthening of the role of economic levers and stimuli in the production activity of enterprises, and further improvement in planning methods.

Ministries, associations and enterprises of the machine building industries began work on implementing the directives of the November (1979) Plenum of the Central Committee of the party "On improving planning and strengthening of the influence of the economic mechanism on the efficiency of production and quality of work." Measures were developed directed to raising the technical standards of production, on creating, assimilating and introducing new machines and progressive technology, and on improving further the quality of the manufactured products.

Old standards are being reviewed and new standards are being created to reduce the amount of materials used in products, reduce all types of power needed for their manufacture and operation, as well as standards that specify the wide use of standardized parts and units.

To reduce considerably the volume of incomplete construction, plans of facilities, whose construction began or those that are being planned for construction and capital investments are being concentrated. The basic problem posed is to accelerate the putting in operation of production capacities, increase considerably the rates of reequipping and modernizing enterprises. Commissions of experts were created to evaluate the technical standards of machines and equipment.

The work of the Scientific-Technical Society of the Machine Building Industry (NTO Mashprom) at the new stage must be directed to solving the most important problem of machine building: accelerate developments and output of new equipment, create modern technological processes; mechanize and automate production; observe the mode of the strictest saving of fuel, power, metal and products; raise the quality of the manufactured product and the productivity of labor.

Machine building, which is the leading sector of the national economy, achieved considerable successes. In the last 15 years, production of about 40,000 new machines, equipment apparatus and devices began. However, there are a number of shortcomings in the work of the industry: great use of metals in manufactured machines and equipment; not high enough rates of introducing new technological processes; considerable waste of metal in machining; slow changeover of individual enterprises to making new products.

Therefore, the creation and introduction of new equipment and modern technological processes, the reduction in the share of manual labor, the increase in technical standards and quality of the manufactured product and the reduction of metal used in it are the most important problems of machine builders at the modern stage. One basic factor that facilitates the solution of the enumerated problem is the expansion in every possible way of the technological, technical and organizational possibilities of production by modernizing and reequiping the enterprises. In this problem, great help must be given by machine tool builders, inasmuch as the reequipment of enterprises depends greatly on the availability of modern equipment -- machine tools with numerically programmed control [ChPU], automatic lines, high speed presses, technological fixtures and tools.

The NTO Mashprom is making a considerable contribution to the scientific technical progress of machine building and metal working.

The primary NTO Mashprom organization of the Leningrad "Elektrosila" Production Association came forth with an important initiative. Simultaneously with the evaluation of the manufactured product, it analyzes the equipment available in the association. Creative brigades formed in the association develop criteria to determine the technical standards of the machine tools and machines and then, on the basis of analyzing the obtained data, make up plans to modernize and reequip the enterprise.

The indicated initiative found followers at other machine building enterprises. The Minsk tractor builders are making a comprehensive investigation of the technical condition of their equipment, uncover production bottlenecks and technological and design shortcomings of machines and outline realistic ways to eliminate them. This work is done by especially created comprehensive brigades that include engineers, designers, technologists, economists, leading workers, as well as scientific workers of a number of institutes.

An important reserve in expanding and developing the creative initiative of the NTO is attracting to the work of reequipping enterprises sections and committees of local NTO Mashprom administrations who can skillfully evaluate the technical and technological levels of all machine building enterprises of the oblast, kray and republic, and help in developing corresponding plans and measures whose implementation will make it possible to solve this problem in the shortest time.

The Sverdlovsk Oblast NTO Mashprom Administration systematically analyzes the work of machine building enterprises of the oblast on using machine tools with ChPU, the use of universal-prefabricated fixtures, the introduction of mechanized and automated warehouses and multi-machine tool servicing. At present, machine tools with ChPU are in operation at 38 enterprises of the oblast; in 1978 some 5,210,000 parts were machined on them. Causes for underloading machine tools with ChPU were uncovered and ways to eliminate this was outlined. As a result of the collected material on using highly productive equipment at enterprises of the Sverdlovskaya Oblast, corresponding recommendations and proposals were made.

The NTO Mashprom directs the efforts of primary organizations of cities, oblasts and republics toward giving aid to institutes, planning organizations and enterprises that do research, development and that produce the modern equipment necessary to modernize and reequip enterprises. Local NTO Mashprom administrations must activate their work on creating new equipment and implementing comprehensive scientific-technical programs.

In primary organizations of NTO Mashprom, it is necessary to discuss more frequently the technical tasks on designing modern machines, prototypes of new equipment and to prepare recommendations for raising their technical-economic standard. It is necessary to tie-in the subject matter of the scientific-technical measures being carried out with the problems of enterprises on developing comprehensive automated sections for machining parts and creating highly productive tools made of synthetic diamonds, superhard materials, new brands of hard alloys, etc.

For example, at its meetings, the Belorussian Republic NTO Mashprom association discusses regularly the activity of primary organizations of enterprises that make technological equipment. The work was considered of the NTO Mashprom primary organization of the Volkovyskiy Casting Equipment Plant on fulfilling the plan for new equipment, as well as the work of the primary organizations of the Minsk Machine Tool Building Plant imeni S. Mikirov and of the Orsha Tool Plant on fulfilling the program to create and introduce highly productive equipment in production.

The NTO of the Minsk Machine Tool Building Plant imeni S. M. Kirov, participating creatively in fulfilling the program, facilitated in the development and introduction of a new in principle method for transporting the machined parts. This makes it possible to implement the movement of the transporter during the working and idle cycles of the machine tool. Moreover, the cutting speed increased to 8-10m/minute by the use of a hard alloy broaching tool, and the accuracy of machining parts and the reliability of the machine tool as a whole were increased. The indicated measures increased the productivity of the series produced machine tool by 2 to 2.5 times. Local NTO Mashprom administrations must increase their concrete help to primary organizations of enterprises in solving modernization and reequipment problems. Sections, committees and social creative associations of NTO Mashprom must utilize widely all forms of scientific-technical work and apply it creatively in practice.

In developing plans to modernize and reequip enterprises, special attention should be given to improving auxiliary production. Observance of technical norms for equipment operation, regular technical servicing, timely and good repairs, as well as the provision of the necessary tools and fixtures will facilitate an increase in the efficiency of production.

Positive experience in the technical improvement of auxiliary production is available in the NTO Mashproms of the Khar'kovskaya, Voronezhskaya, Volgogradskaya, Zaporozhskaya, Saratovskaya and other oblasts.

Due to the initiative of the NTO Mashprom of the Gor'kovskiy Motor Vehicle Plant, a number of plans was developed and introduced to modernize the technological equipment which made it possible to increase its productivity by 15 to 20%. Work is being done to reduce repair time by 15%, and idle time by 8%.

Good experience in helping repair services is available in the L'vov Oblast NTO Mashprom Administration. The tool production section of the administration aided greatly in introducing 79 technical measures, which raised considerably the quality of products of tool shops of the machine building enterprises in the oblast. Among the indicated measures should be noted the creation of sections for assembling universal assembly fixtures, the introduction of diamond grinding of fixtures, the introduction of the carbo-nitration process for taps made of high speed cutting steel, which increased the life of the taps 1.8 to 2 times.

The Khar'kov Oblast NTO Mashrpom Administration is doing a great amount of work to reduce manual labor in tool manufacturing by using universal-assembly readjustable fixtures. The administration gives enterprises the necessary technical and methodological help, organizes seminars, exhibits and advanced experience schools. This facilitates the creation of new sections for designing and making universal-assembly fixtures and accessories at the plants of the oblast and in organizing basic services. In three years of the Tenth Five-Year Plan period alone, 18 sets of such fixtures were introduced at ten Khar'kov plants saving 150,000 rubles annually. By the end of the five-year plan, it is planned to introduce 60 sets of new types of universal assembly fixtures and equipment.

The decrees of the November (1979) Plenum of the Central Committee of the party and the decree of the Central Committee of the party and the USSR Council of Ministers "On improving planning and strengthening the influence of the economic mechanisms on raising the efficiency of production and quality of the work" direct organizations of the NTO Mashprom to help enterprises of the industry more actively in solving national economic problems and implement activity on raising the efficiency of machine building and the quality of the manufactured products. It is necessary to utilize more widely the possibilities of the scientific society of the industrial sector for the successful fulfillment of the plan for the final year of the Tenth Five-Year Plan period and of the five-year plan as a whole.

Special Design Machine Tools

Moscow STANKI I INSTRUMENT in Russian No 2, Feb 80 pp 3-4

[Article by I.V. Vorotyntsev: "Increasing the Technical Level of Heavy and Unique Machine Tools"]

[Text] Equipment produced by the Ul'yanovsk Heavy and Special Design Machine Tools for heavy parts is used widely in various areas of heavy machine building. The most important problem faced by manufacturers is to increase the accuracy and productivity of heavy and special design machine tools. To solve this problem, it is necessary to arrange for machining of parts with one setting, since reducing the number of settings reduces machining time and increases manufacturing accuracy. It should be noted that machining with one setting is of special importance in manufacturing heavy parts because they have a relatively low unit rigidity. Therefore, each resetting of such parts reduces machining accuracy.

In the first years of its production activity, the Ul'yanovsk Plant of Heavy and Special Design Machine Tools assimilated the manufacture of universal vertical-milling machine tools with a cross table (width of table 630, 800 and 1000mm); one-andtwo-stand plano-milling machine tools with sleeve milling headstocks (width of table 1250, 1600, 2000 and 2500mm), as well as a number of special machine tools.

During the Ninth Five-Year Plan period, series production was organized of vertical milling machine tools with ChPU, as well as the production of special design plano-machining combination machine tools models [illegible] and 6650 of the straddle type (width of tables 4000 and 5000mm, machine tool weight up to 750 tons, largest weight of machined part 200 tons).

In the Tenth Five-Year Plan period, the basic products of the plant are heavy and special design machine tools, machine tools with ChPU and multitool machine tools. The development and manufacture of automatic lines began. The use of the indicated equipment increases machining productivity three to five times.

The plant began manufacturing multitool plano-machining machine tools. In their design, the sleeve spindle headstocks were replaced by milling-drilling headstocks of the carrier type (equipped with replaceable angular heads) which can be used to machine parts on five sides with one setting. On machine tools with table widths of 4000 and 5000mm, there is a possibility of installing (on any milling-drilling headstock) superimposed planing or grinding units.

In three years of the Tenth Five-Year Plan period, the plant organized series production of special design plano-machining combination machine tools models 6640 and 6650; milling-drilling machine tools (equipped with carrier type headstocks) models 6612U, 6616U, 6620U and 6625U; multitool machine tools model 6560MF3 with automatic tool change. A prototype was made of a special design machine tool model 6620MF4 with automatic tool change (width of table 2000mm).

New machine tool designs use the following units that considerably increase their reliability in operation: hydrostatic guides; rolling guides equipped with superimposed annealed planks, dc motors that improve the dynamic characteristics of the drives; hydrostatic worms and ball screws in gear drives; a digital system to read the machine tool movements.

The following scientific research and experimental work is being done to provide a high technical standard of the equipment made at the plant: the finishing off of new in principle units that determine the quality and technical standard of the machine tools; the investigation of new ChPU systems, digital indication systems and tracking thyristor drives with high torque motors; the development and introduction of adaptive systems for controlling the milling process; an investigation of machine tool reliability under operating conditions.

Work is being done on the automation of design and research by computers. Computers are used to calculate the strength, rigidity and life of parts and units of machine tools, and dynamic calculations (including comprehensive ones) are made of the main drives and the feed drives, as well as the carrying systems of the machine tools.

At present, designs of semiautomatic lines are being developed as well as comprehensively automated systems for machining large parts. Work was completed on a semiautomatic line for comprehensive machining of tubings of various type-sizes. The line includes milling and unit-head drilling machine tools operating in an automatic cycle that move the tubing (with its carrier) sequentially from one machine tool to another and has a transport system for returning it to its initial position. The design of the line provides for the mechanization of the positioning and fastening of the tubing, cleaning it of dust and cuttings, as well as gathering and removing the cuttings.

A complex of such lines is being built into the technological production process of tubings at metallurgical plants. The annual saving from introducing six semiautomatic lines for comprehensive machining of tubings will be about seven million rubles.

The use of automated sections of machine tools with ChPU controlled by computers is economically effective at small and medium series production facilities. In 1980, the plant will manufacture a prototype of a model ASK-30 comprehensively automated system designed for machining base parts weighing up to five tons.

The system includes special design multitool machine tools with a vertical spindle (using model 6620MF4 machine tool as a basis) and with a horizontal spindle (using model 2651F2 machine tool as a basis), a monitoring-measuring machine and a transport storage system. The system will be controlled by a computer which will monitor the implementation of the technological process, the change of tools and the loading and unloading of parts.

The use of the model ASK-30 comprehensively-automated system will make it possible to increase productivity 2.5 to 3 times and save 825,000 rubles annually. In the next five-year plan period, it is planned to organize series production of such systems, as well as to manufacture a prototype of a model OK-3 automated complex (with an automatic change of tools and heads) for machining special design parts weighing up to 200 tons.

The basic direction of a further increase in the technical standard of heavy and special design machine tools is their wide use in manufacturing new, highly efficient systems, units and associated products including the following: ChPU systems using large-scale integrated circuits; sets of electrical equipment for machine tools with ChPU using contactless electric apparatus with programmed instruction apparatus; high power dc motors with a 5:1 regulating range (at constant power); drives with high torque motors with permanent magnet excitation; contactless sensors of linear and circular motions; with large rolling screw pairs normalized and standardized fixtures; progressive tools for machine tools with ChPU; systems for automatic change of tools.

Creative Scientific Research

Moscow STANKI I INSTRUMENT in Russian No 2, Feb 80 pp 5-7

[Article by A.M. Bessol'tsev: "Basic Directions of Scientific-Investigative Work in the Creation of Heavy and Unique Machine Tools"]

[Text] The creation of heavy and special design machine tools at the present technical level demands a considerable volume of calculations and scientific research work. The Ul'yanovsk Main Special Design Bureau of Heavy and Milling Machine Tools (GSKBFS), in working on the design of the indicated equipment, constantly increases the volume of scientific research work (NIR) and experimental work (ER) which is attested to by the data cited below:

Year	1960	1966	1971	1975	1978
Share of NIR and ER in total cost of work, %	8.6	26.1	22.5	27.5	27.8
Rise in volume of NIR and ER (in cost), %	100	621	592	1076	1337
Share of workers in NIR and ER, %	6.5	14.1	15.9	14.4	19.5
Increase in share of workers in NIR and ER, %	100	389	456	528	711

To most fully recognize, analyze and take into account all the factors that affect the design and operation of the machine tools, the NIR and ER in the GSKBFS span a number of basic divisions whose content and structure are described below.

Creating scientific research reserve for designing.

1. Gather, analyze and correlate data (study technical-economic and operating data on similar machine tools operating in domestic industry and abroad; analyze and correlate obtained data by computers; technical-economic substantiation of designs of new machine tools).

2. Creating and finishing off promising units and mechanisms (for clamping tools and intermediate products, for automatic change of tools, reading movements and digital indication, lubricating the table guides, etc.).

3. Developing scientifically substantiated methods for designing basic systems for heavy and special design machine tools (carrying systems, main drives and feed drives).

Calculation and experimental checks for adopted design solutions.

1. Calculation, analysis and finishing off of basic units of machine tools (the determination of the dynamic characteristics of units and machine tools; determination of indicators of static and dynamic accuracy of machine tools; optimization of material and power used in machine tools).

2. Experimental check of individual units and mechanisms (devices for transporting cuttings and cooling, slide headstocks, reducers without gaps, systems for SOZh [Lubricating-cooling liquids] and power feeds to units being moved, sets of devices for controlling machine tools, ChPU systems, etc.).

Mechanization and automation of calculated scientific research and design work.

1. Analysis and processing of research data (atuomation of dynamic and metrological investigations of machine tools and investigations of feed drives).

2. Analysis and correlation of design data (automation of strength, geometric and comprehensive calculations; automation of design and graphic work, including detailing on graph-plotters, creating a file of detail drawings for designing in the mode of "designer-computer" dialog, designing schematic and electric wiring daigrams, designing machine tools from modular units).

3. Analysis and correlation of management data (monitoring the fulfillment of decisions, accounting of the fulfillment of the plans of divisions and the thematic plan of the design bureau, accounting of design costs, planning the work of design divisions).

In creating scientific-technical reserves for designing, it is necessary to distinguish the following work.

Scientific research work on creating and finishing off new design solutions for their subsequent use in machine tools being designed. In 1961-1962, models were investigated of various designs of slides for special design plano-machining machine tools, which made it possible to create an optimal design of slide guides which met production, and operation requirements and have remained practically the same to this time.

At the same time, investigations were made on various types of static converters for main drives and feed drives. Drives were investigated using thyratrons, ignitrons, magnetic amplifiers and thyristors. As a result, drives using thyristor converters were developed whose use at the Ul'yanovsk Plant of Heavy and Special Design Machine Tools raised considerably the quality of the electrical equipment of the machine tools and reduced the cycle of their manufacture.

Thyristor servo-drives (for machine tools with ChPU) were investigated under laboratory and production conditions with high torque drives and drives used in the high torque mode. The following devices were created on the basis of this work: a device for increasing the static accuracy of the servo-drive; a device for compensating errors in machining due to the reversal of the servo-drive and the play in the drive; compensation for dynamic errors of the drive. The use of the indicated devices made it possible to create a servo-drive operating with large (up to 1mm) play in the kinematics of the drive.

Various types of clamps, switching mechanisms, lubrication systems and other devices were created and finished off and experimentally used in machine tools designed at the GSKBFS.

Economic investigations in the predesign stage. In preparing for the design of new comprehensively standardized series of milling machine tools, original methods were created and used at the GSKBFS for the selected investigation of various industrial sectors to identify the technological needs of the national economy in a given type of equipment and to determine an efficient structure of a milling machine tool pool and the economic effect of standardizing types and sizes. The relationship (Fig. 1) was also determined and investigated between the laboriousness and assembly of machine tools and how large the series of production should be, since this is of great importance in establishing economically expedient standardization limits.

On the basis of these investigations, the necessity for changing the structure of the milling machine tool pool to the side of a sharp increase in the number of designs without cantilevers was determined. This was later confirmed by domestic and foreign machine tool building.

The relationship between the cost and laboriousness of making units and mechanisms of heavy machine tools, and factors determined in the process of their design was also studied. As a result of a thorough correlational analysis, the relationship between the laboriousness of manufacturing the unit and its weight, the number of parts in the unit and the laboriousness of the design was determined.

The use of the relationships found makes it possible to compare various versions of the development in the process of design to a fair degree of accuracy.

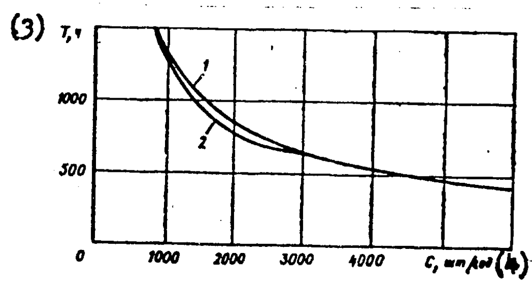

Fig. 1. Relationship between laboriousness T of manufacturing and assembly of cantilever milling machine tools and the size of the series output C:

1. calculated
2. actual
3. T, hours
4. C, pieces per year

Analysis and correlation of data needed by the designer. Work is being done on a scientifically substantiated selection of data needed by the designer (especially, in the initial design stages), containing information on best design solutions, similar to domestic and foreign equipment, its utilization in industry, existing patents, etc. Computers are used to obtain scientific-technical data efficiently, as well as for the search and analysis of patent data.

In checking and finishing off the adopted design solutions, the following work is of the greatest importance: checking and design calculations and investigations of feed drives, necessary due to the complexity of providing the required smoothness of travel, and the accuracy of positioning of heavy units of plano-machining machine tools. To obtain the required accuracy of positioning is especially important for machine tools with ChPU.

Checking calculations are made by digital computers and design checks -- by analog computers.

For a check calculation of drives whose final link are a screw or worm-rack drive, a complex of programs was created to determine the strength and give of all components of the drive, necessary for the preliminary tension of the final link, the rigidity balance, the play in the drive and other characteristics [1].

Analog computers used for the design and investigation of feed drives make it possible to simulate more accurately than digital computers the physical essence of the problem (taking into account the non-linearity, not simplify the structural ties and change them efficiently) and monitor the obtained results by an oscillograph or recorder. This makes it possible already at the design stage to analyze the versions efficiently, select the optimal design of the machine tool with the improved technical characteristics and reduce costs for experimental work and finishing off the machine tool [2].

At present, there are completed or in the check-out stage the solutions for the following problems: investigation of smoothness of travel of units along horizontal guides when idling or in process of cutting; investigation of the optimal rigidity of the feed drives of machine tools with ChPU; investigation of automatic systems for hydraulic unloading of units.

Investigations made by computers are supplemented by natural tests of machine tool prototypes that make it possible to determine the final parameters of the drives, the size of their individual components, as well as to obtain the necessary experimental data for future use in experimental models of the drives.

The work done at the GSKBFS made it possible to increase the rigidity of the feed drives of the special design plano-milling machine tools (with the table widths of 4000 and 5000m) 2 to 2.5 times and to identify reserves for its further increase [3].

Investigation of the dynamics of the main drives and carrier systems. On the basis of theoretical developments [4 and 5] a program was created and introduced at the GSKBFS to calculate the vibration resistance of machine tools taking into account the dynamic characteristics of the carrier system, the main drive, the feed drive and the cutting process by a multiple-blade tool. Calculation results in accordance with the indicated program are adequately close to the experimental ones.

The calculation of vibration resistance already makes it possible at the design stage to select an optimal design of the carrier system and the drives of the machine tool. For example, the use of the calculation results in developing a new series of vertical milling machine tools made it possible to increase considerably the power of the main drive without reducing the vibration resistance and increasing the weight of the machine tool.

Development of adaptive systems for controlling cutting modes. The use of adaptive systems increases the productivity of machining considerably. Such systems are being developed at the GSKBFS for machine tools with ChPU, as well as for universal and special machine tools.

A single-parametric adaptive control system for multispindle milling machine tools that operate with face cutters, stabilize the cutting power by changing the instantaneous feed. When the surface area of cutting or machining allowance changes five times, the static area of the system does not exceed 10%. The transition time of the process with a step change in the allowance is 0.3 to 0.5 seconds. The use of the system increased machining productivity by about 30-40%. It is used in operation at the Ul'yanovsk Plant of Heavy and Special Design Machine Tools.

A single-parametric adaptive control in the special design plano-machining model 6650-10 machine tool (5000mm table width) was developed and introduced. It stabilizes the power of the main drive and limits the vibration level of the carrying system of the machine tool by changing the instantaneous feed.

A two-parametric adaptive scanning was developed and has passed through experimental tests. It stabilizes the current of the most heavily loaded motor of the main drive by regulating the feed, and reduces the level of natural machine tool vibrations by changing the frequency of spindle rotation. The use of a two-parametric system (compared to a single-parametric) increases machining productivity by about 30%.

Work was done on testing and introducing adaptive control systems in models BOR-1 and ADF-1B machine tools.

Investigation and introduction of ChPU systems and digital indication devices. Work is being done to raise the quality and increase the reliability of ChPU systems for vertical-milling machine tools with cross tables. The reliability of machine tools with ChPU was increased due to a number of measures taken involving the ChPU system itself, as well as the design of the machine tool and its electrical equipment. Similar work is being done on investigating and introducing digital indication devices.

Investigations of systems for lubricating the table guides of plano-machinery machine tools. As a result of the work done, there was considerable improvement in the dynamic characteristics of the guides and an increase in the positioning accuracy and load carrying capacity of the tables, as well as a reduction in the consumption of lubricant fed to the guides.

For a number of years, work was done at the GSKBFS on mechanizing and automating calculation and scientific research of design by using computers. At present, computers are used for the following: analysis and correlation of data at the predesign stage; making investigations; making calculations; preparing summary documentation; making drawings and graphs; automating the design control process.

Over 30 programs were developed and introduced (including comprehensive ones) that cover all basic types of calculations necessary in designing machine tools.

Of special interest is the use of computers for automating investigations. The GSKBFS uses measuring complex model TsIS-IM which makes it possible to automate dynamic tests of machine tools and thereby reduce the time for testing and obtaining initial data for creating optimal designs. In the future, it is proposed to develop similar complexes to analyze the shape of machine tool vibrations, determine the characteristics of the mechanical part of the feed drive, make metrological investigations of the measuring systems of the machine tools with ChPU, etc.

The following developments are in the introduction stage: using computers to make working drawings of typical parts (shafts, bushings, flanges, gears); create a drawing file in the computer memory; design in the mode of a dialog with the computer, etc. The use of the computers increased the productivity of calculations (compared to 1959) by 8.3 times.

Besides scientific research work, a large volume of experimental work is being done at the GSKBFS in the process of designing units and parts that determine the novelty and technical standard of machine tools.

These units are made in the experimental shop and pass various tests (dynamic, life, etc.) after which they are sent for production. The basic attention is given to experimental finishing off of mechanisms and units of machine tools with ChPU and multiple tool machine tools.

To study the designed machine tools under operating conditions, the GSKBFS conducts inspections annually at client plants by especially created groups consisting of various specialists.

Measures carried out the GSKBFS NIR and ER, as well as other measures described in the article facilitate raising the technical standards, quality and reliability of heavy and special design machine tools.

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Direct Drive Control

Moscow STANKI I INSTRUMENT in Russian No 2, Feb 80 pp 18-21

[Article by V.I. Volovoy, M.N. Koval', and A.G. Lavrekho: "Research and Acceptance of Direct Drive Devices in Heavy Machine Tools from the ChPU"]

[Text] Loop ChPU systems with a servo-drive are being used more and more widely in heavy machine tools. The considerable influence of the servo-drive on the resulting machining error was established [1]. Components of machining errors introduced by the servo-drive are basically determined by the design of the drive, the type of actuating motor and the type of position sensor.

The special features of the ChPU system (Fig. 1) used in certain heavy milling-drilling machine tools of the Ul'yanovsk Plant of Heavy and Special Design Machine Tools and other machine tool plants are: the presence of a speed error compensation channel (KSO) along with the servo position control loop (BSP unit); the use of a high torque motor with a direct connection to the lead screw of the ball-and-screw pair without a reducer; the use of a linear position sensor (of the inductosin type or the DLM-11).

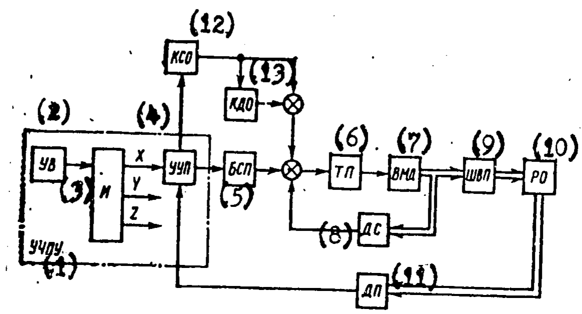

Fig. 1. Functional circuit of a loop ChPU system with a servo-drive:

1. UChPU--ChPU device
2. UV -- input device
3. I -- interpolator
4. UUP -- drive control device
5. BSP -- route tie unit
6. TP -- thyristor converter
7. VMD -- high torque motor
8. DS-- speed sensor
9. ShVP -- ball-and-screw pair
10. PO -- actuator
11. DP -- position sensor
12. KSO -- speed compensation unit
13. KDO -- dynamic error compensation unit

A number of properties of high torque motors provides a quantitative and qualitative improvement in the characteristics of the feed drives of machine tools. In particular, the high ratio of starting current and torque facilitate obtaining good dynamic indicators of the drive. However, these possibilities are not always realized fully. Thus, the investigation of the ChPU system (Fig. 1) containing type N33-2M ChPU device (UChPU), a BU-3608 thyristor converter and 2PB-160L and PBV-132M motor domestically made and TTRB-5302 made by the Inland Co. (United States) showed that in dynamic modes, the starting current of the motors did not reach the maximum allowable value. As a result, the duration of the transient process and dynamic errors are greater than the rated ones and do not depend much on the type of the motor and the characteristics of the thyristor converter. In the servo mode (if the control signal has a shape of a jump in speed), the acceleration time to 1000 rpm for the indicated motors was 0.1, 0.09 and 0.13 seconds respectively.

The way the components of the servo-drive (for example, the sensor) are built into the machine tool, the nature of the interaction between the motor and the components of the machine tool, etc. affect considerably the accuracy of the servo-drive. Below are shown results of investigations of the servo-drive taking into account the enumerated features.

The investigation was made on a heavy vertical milling-drilling model 6560MF3-2 machine tool (with automatic tool change). The machine tool has a cross table moving along X and Y coordinates with a 630 x 1600mm working surface and a milling-drilling headstock with a 15kw main motor moving along the Z coordinate. Friction rolling couples were used for the basic plane of the table guides and carriages, and for the side edges of the headstock guides; friction-sliding couples were used for the side edges of the table guides and carriages, and the basic plane of the headstock guides. The feed drive is made on the basis of a ball-and-screw couple (screw diameter 80mm, pitch 10mm) and high torque TTRB-5302 motors fed by BU-3608 thyristor converters, a type IN33-51 UChPU and type DLP (inductosin) linear position sensors. The basic characteristics of the investigated drive were: nominal torque of the motor shaft -- 3.8kg-force.m; limits of working feeds -- 1-6600mm/minute; fast travel speed -- 9.6m/minute; total idle travel in the kinematic circuit -- 20 to 40 micrometer; a Q-factor of the servo control loop with respect to position -- 20 second^{-1}.

Drive errors in the static modes (positioning), the dynamic errors in machining internal angles, as well as the influence of acceleration and deceleration on the positioning time were investigated.

Static accuracy of the servo-drive. The finishing off error of a single pulse was determined as the difference between the assigned movement in the pulse mode and the actual finishing off movement. The investigation was made for the three machine tool coordinates (X, Y, Z) and for two values (10 and 1 micrometer) of discretness of the UChPU. The obtained results are shown below.

Discreteness, micrometer	10	10	10	1	1	1
Coordinate	X	Y	Z	X	Y	Z
Error, micrometer:						
average value	0.8	0.7	1.05	0.75	0.8	0.6
rms deviation	0.26	0.22	0.34	0.24	0.26	0.19

It should be noted that errors in finishing off a single pulse hardly change for a reduction in the discreteness of the UChPU, as well as when varying the Q-factor of the servo loop within limits of 15 to 35 seconds^{-1} and, for the considered case, are determined basically by the smoothness of the motion of the unit (maximum jump) and the intrastep error of the position sensor.

The positioning error was determined as the difference between the assigned and actual positions of the unit when it was moved many times by the same distance. The results obtained are shown in the Table and on Fig. 2.

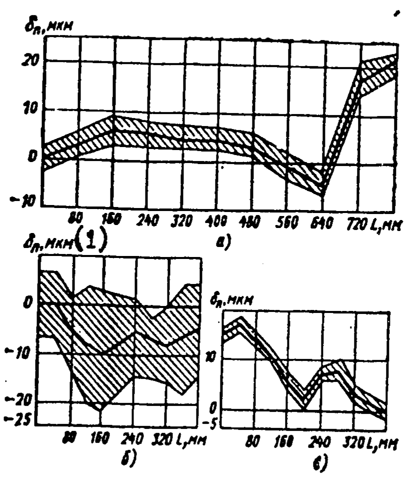

Fig. 2. Error $\delta_{п}$ in positioning the machine tool units along coordinates X(a), Y(b) and Z(c): curves -- average error value; cross-hatched zone -- actual error scattering field; L -- positioning route.

1. Micrometer

For the considered servo-drive, the positioning error is determined basically by the intrastep, accumulated errors of the position sensor and the errow with which the unit is held in the stationary position (see below).

Table

Coordinate	Direction of motion	Error, micrometer			
		Accumulated maximum		RMS deviation	
		actual	permitted	actual	permitted
X	right	21.4	40	1.3	6
X	left	24.6	40	1.9	6
Y	forward	8.5	30	5.0	4
Y	backward	14.5	30	7.5	4
Z	up	17.2	50	1.0	6
Z	down	16.4	50	0.9	6

The large field of error scatter in positioning the table along the Y coordinate (see Fig. 2) is due to the arrangement adopted on the machine tool for fixing the guides and the disposition of the lead screw and sensor. The presence of an arm between the point of application of the pulling force on the screw and the action line of the friction force in the basic guide leads to the fact that in positioning (braking and stopping) the carriages, it is possible to turn the table slightly in the horizontal plane. As a result, an ambiguity originates in the position of any fixed point of the table, located in the cutting zone, monitored by the position sensor of the servo-drive. When the pulling force on the screw reverses, the carriages reorient themselves with respect to the guides. To reduce deviations and increase the accuracy of positioning, it is expedient to place the positioning sensor closer to the spindle and eliminate the reorientation of the carriages by improving the fixing of the guides.

Errors in the position of the stationary unit. In the process of investigation, it was established that after the unit is shifted to an assigned position, it is not held by the servo-drive stationary but "rocks" with a randomly changing frequency (about 0.1 to 0.5Hz) and an amplitude of several micrometers (Fig. 3). This phenomenon is inherent in servo-drives containing components with considerably non-linear input-output characteristics in the control loop.

In the case being considered, due to the nonlinear characteristc of the rigidity of the ball-and-screw couple and the nonlinear load (friction forces in the guides), the unit moves in steps (0 to 5mm/min) at small feeds; in this case, the value of the first step reaches several micrometers. Moreover, the position of the unit in the dead travel zone of the kinematic circuit is indefinite. The drift in the characteristic of any of the links of the servo-drive causes a rotation of the motor shaft, which moves the unit by the value of the step. The mismatch that occurred along the route returns the unit to its previous position and the process is repeated.

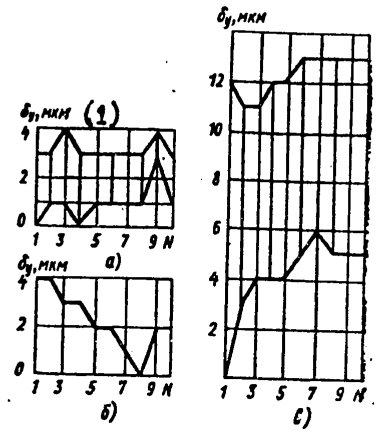

Fig. 3. Diagrams of errors δ_y in holding stationary machine tool units along coordinates X(a), Z(b) and Y(c); N -- number of measurements;

1. micrometer

The "rocking" zone of the stationary unit is a component of the positioning error (including the error of the unit returning to its initial position). For some combination of drive and machine tool parameters, this component may be considerable and its elimination is a reserve for increasing the static accuracy. This error component is practically absent on the model 6560MF3-2 machine tool along coordinate Z (Fig. 3b) due to the fact that because of the nonideal unloading of the headstock, the ball-and-screw couple is always loaded in one direction.

Dynamic accuracy of the servo-drive. Recently, the working feeds on machine tools with ChPU increased to 5-6m/min, the speed of the fast travel -- to 10m/min, while the acceleration time to the maximum feed and the braking time from the maximum feed to zero decreased to 0.1-0.3 seconds. The dynamic errors of the drive increase considerably under such conditions. For example, on the model 6560MF3-2 machine tool, the drive error when braking from a feed to 0.8m/min. to full stop is such that the machining error of an internal right angle at this feed is approximately 0.17mm. When braking from the fast travel speed of 9.6m/min, the error reaches 1.5mm; therefore, to preserve the efficiency of a drive with a sensor that has a pitch of less than 3mm, it is necessary to introduce a mismatch accumulator. Special measures must be taken to insure that dynamic and machining errors remain within allowable limits in the considered modes.

The dynamic error of the servo-drive may be reduced efficiently by introducing a signal proportional to the derivative of the assigned speed of travel [2] in the control channel. Such a signal may be produced by the KDO unit connected as shown in Fig. 1. We will determine conditions for compensating the dynamic error by using the method of error coefficients [2].

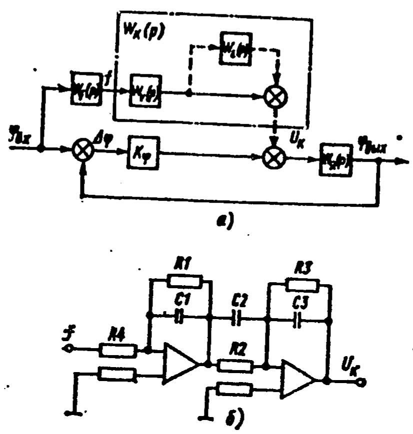

Fig. 4. Circuit of the servo-drive (a) and schematic diagram of the compensation unit (b): $W_f(p)$, $W_v(p)$, $W_a(p)$ are transfer functions respectively of the differentiator and speed and dynamic errors compensation units; $W_K(p)$ -- resulting transfer function of the compensation units; $W_\Omega(p)$ -- transfer function of the series connected regulated electrical and mechanical drives and the position sensor; K_φ -- phase discriminator transfer coefficient; $\varphi_{вх}$, $\varphi_{вых}$ and $\Delta\varphi$ -- input and output signals and their mismatch; f -- frequency of program pulses; U_K -- compensation voltage of speed and dynamic errors.

Fig. 4a shows the circuit of the investigated drive. The equivalent transfer function for the error is

$$\Phi_\Delta(p) = \frac{\Delta\varphi(p)}{\varphi_{вх}(p)} = \frac{1 - pW_к(p)W_\Omega(p)}{1 + K_\varphi W_\Omega(p)} =$$

$$= \frac{m_1 p + m_2 p^2 + \dots + m_q p^q}{n_1 p + n_2 p^2 + \dots + n_h p^h} = \frac{m_1}{K_\varphi K_\Omega} p +$$

$$+ \frac{1}{K_\varphi K_\Omega}\left(m_2 - \frac{m_1 n_1}{K_\varphi K_\Omega}\right) p^2 + \dots \qquad (1)$$

Here $\varphi_{вх}(p)$ and $\Delta\varphi(p)$ -- the input effect and the error in its finishing off; $W_{\Omega}(p)$ and K_{Ω} -- transfer function and amplification coefficient of series connected regulated electrical and mechanical drives and the position sensor; $W_K(p)$ -- resulting transfer function of speed and dynamic error compensation functions; K_{φ} -- phase discriminator transfer coefficient; m_i, n_j -- coefficients of polynomials of transfer function $\Phi_{\Delta}(p)$, determined by the parameters of the components of the open loop of the drive; q and h -- number of members in the polynomials; $K_{\varphi} K_{\Omega} = K_v$ -- Q-factor of the servodrive.

It is possible to find from expression (1) speed and dynamic error coefficients:

$$A_v = m_1 K_v^{-1}; \quad A_\varepsilon = K_v^{-1}(m_2 - m_1 n_1 K_v^{-1});$$

the condition for compensating for these errors is $A_v = o$ and $A_{\varepsilon} = 0$.

For a compensation unit realized in practice (Fig. 4b), the transfer function is

$$W_к(p) = \frac{U_к(p)}{f(p)} = K_к \frac{T_2 p + 1}{(T_1 p + 1)(T_3 p + 1)},$$

where f and U_K -- frequency of program pulses and the compensating voltage of speed and dynamic error tracking; K_K, T_1, T_2, T_3 -- transfer coefficient and time constants of the compensation unit [$K_K = R_1R_3/(R_2R_4)$; $T_1 = R_1C_1$; $T_2 = R_2C_2$; $T_3 = R_3C_3$; R_1-R_4 -- resistance of resistors R1-R4 (see Fig. 4b); C_1-C_3 -- capacitance of capacitors C1-C3].

Taking these expressions into account, the coefficients of equation (1) may be written by parameters of the drive and the components of the compensation unit:

$$m_1 = 1 - K_к K_\Omega; \quad m_2 = T_\Omega + T_I + T_1 + T_3 - K_к K_\Omega T_2 - K_к K_\Omega \times \times (T_\Omega + T_I); \quad n_1 = 1 + K_v \ (T_\Omega + T_I + T_1 + T_3). \tag{2}$$

where T_{Ω} and T_I -- time constants of the correcting circuits of the speed regulator and the thyristor converter current regulator.

Taking into account expressions (2), the condition for the absence of a speed error assumes the form $A_v = 0$, if $K_K = 1/K_\Omega$; the condition for an absence of a dynamic error for $A_v = 0$ has the form $A_\varepsilon = 0$, if $T_1 + T_3 - T_2 = 0$. The latter expression makes it possible to determine the value of differentiating capacitance C_2 at previously found parameters of other components of the compensation unit: $C_2 = (R_1C_1 + R_3C_3)/R_2$.

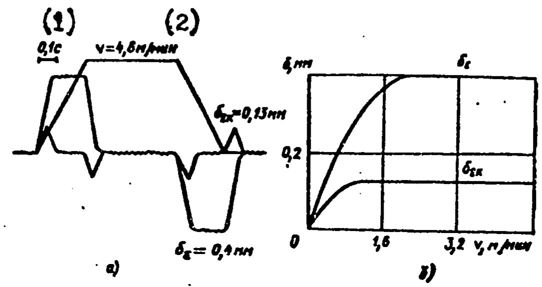

Fig. 5. Oscillograms of dynamic errors of drive (a) and their dependence on speed v of tracking (b); $\delta_{\varepsilon K}$ and δ_ε -- dynamic errors of drive with compensation and without compensation.

1. 0.1 seconds
2. m/minute

The efficiency of the compensation unit was checked experimentally on a laboratory servo-drive consisting of a type N-33-2M UChPU a BU-3608 thyristor converter, a PBV-132M high torque motor (torque 3.5kg-force.m), a flywheel with a moment of inertia of $0.06 kg.m^2$ and a VTM-IV sensor. Fig. 5 shows the oscillograms of dynamic errors and their dependence on the tracking speed in cases of the presence and absence of a compensation channel for these errors.

The efficiency of the dynamic compensation was finally evaluated by the results of part machining on the model 6560MF3-2 machine tool (Fig. 6a). The machining conditions were as follows: material of the intermediate product TsAM alloy; end cutter -- 20mm diameter; allowance -- 3mm; cutting depth -- 10mm; equidistance radius equal to zero. The results of the investigation (Fig. 6b) showed the high efficiency of the considered method for compensating the drive errors.

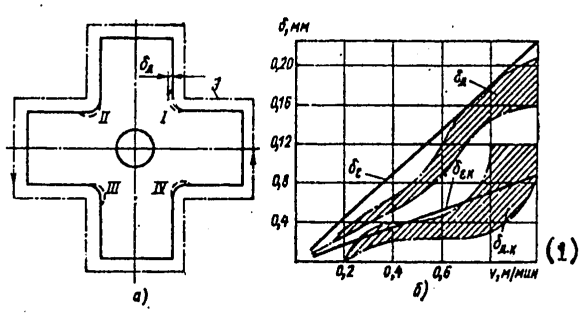

Fig. 6. Effect of dynamic compensation on accuracy of machining of internal right angles: $\delta_{д,к}$ and $\delta_{д}$ -- error scattering field of part machining for 1-IV zones with and without compensation of dynamic error of drive; δ_{ε} and $\delta_{\varepsilon к}$ -- same as in Fig. 5; Э -- equidistance.

1. m/minute

Selection of the acceleration and braking times for the drive. To reduce the idling time of the machine tool units, an effort is made to reduce the time of accelerating to the fast speed (and the braking time) to 0.1-0.2 seconds. However, dynamic overloads originate in this case in the servo-drive for such short times of accelerating and braking. Special measures must be taken to provide for its efficiency. An analysis shows that the effort to reduce the time of acceleration and braking to a minimum is not always substantiated technically and economically.

Fig. 7 shows calculated relationships (checked experimentally) of the positioning time of the unit for various travels L, various speed $v_{б.х}$ of the fast travel and various acceleration times t_p to the speed of the fast travel (and braking t_T). Also shown are relationship between coefficient η of relative increase in positioning time, which is equal to the ratio of positioning time in a given mode to positioning time at $v_{б,х} = 9.6$m/min and $t_p = t_T = 0.2$ seconds.

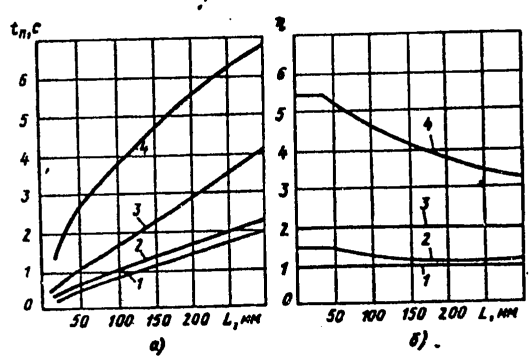

Fig. 7. Relationships between time of positioning t_n (a) and its relative increase η (b) and acceleration time t_p and braking time t_T, speed $v_{\text{б.х}}$ of the fast travel and length L of travel: 1 -- at $v_{\text{б.х}}$ = 9.6m/min, $t_p = t_T$ = 0.2 sec; 2 -- at $v_{\text{б.х}}$ = 9.6m/min, $t_p = t_T$ = 0.4 sec; 3 -- at $v_{\text{б.х}}$ - 4.8m/min, $t_p = t_T$ = 0.4 sec; 4 -- at $v_{\text{б.х}}$ = 4.8m/min, t_p = 2 sec, t_T = 4 sec.

An analysis of Fig. 7 indicates that if increasing $v_{\text{б.х}}$ from 4.8 to 9.6m/min and decreasing t_p and t_T from 2-4 to 0.4 seconds reduces considerably the positioning time of the units, then decreasing t_p and t_T from 0.4 to 0.2 seconds for all other conditions being equal is not as efficient. The experimental efficiency of the indicated measures was evaluated by finishing off the control program of 148 items. The machining program of the part by 15 tools contained 55 changes from position to position 40 to 500mm long. For $v_{\text{б.х}}$ = 4.8m/min, t_p = 2 seconds and t_T = 4 seconds (see curves 4 in Fig. 7), the machine time for finishing off the program was 50 minutes and for $v_{\text{б.х}}$ = 9.6m/min and $t_p = t_T$ = 0.4 seconds (see curves 2), the time of finishing off the program decreased only by 3.5 minutes.

Conclusions

1. The basic factors that determine the accuracy of finishing off single pulses by the servo-drive and the accuracy of positioning units are: the intrastep and the accumulated errors of the linear position sensor, the smoothness of a movement of the units at small feeds and the method for building in the lead screw and the position sensor.

2. The developed method and device for compensating the dynamic error reduce the errors of the servo-drive considerably, as well as the error in machining parts in dynamic modes and is recommended for implementation in existing and newly developed ChPU systems.

3. A reduction (for the purpose of increasing the productivity of machining) of the accelerating and braking times (to the speed of the fast travel) to a technically minimum possible value (about 0.1 seconds) in heavy machine tools with ChPU is not worth while in the majority of cases; the recommended time for acceleration and braking is about 0.4 seconds.

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Development of Technology

Moscow STANKI I INSTRUMENT in Russian No 2, Feb 80 pp 24-25

[Article by N.N. Beydel'spakher: "Development of the Technology of the Manufacture of Heavy and Unique Machine Tools"]

[Text] The expansion of production of heavy and special design machine tools and the leading development in the production of machine tools with ChPU require continuous improvement in the technology of their manufacture.

The basic trend in the development of technology is specialized comprehensively mechanized sections. This makes it possible to use for single unit and small series production highly productive specialized equipment, machine tools with ChPU, universal assembly readjustable fixtures (USPO) and universal transportation-warehousing facilities.

The Ul'yanovsk Plant of Heavy and Special Design Machine Tools did a great amount of work to reequip production.

The machining of basic and housing parts was transferred from universal machine tools to machine tools with ChPU, multiple-tool machine tools, combined plano-machining machine tools and machining complexes. The plant has a specialized section for machining various types of shafts up to 800mm long. The section (see Fig.) consists of a line of machine tools and an automated transportation warehousing system. The warehouse shelves are located parallel to the line of the machine tools and the warehouse is equipped with a stock-piling machine. A double worm conveyor 40 meters long is provided to remove the cuttings.

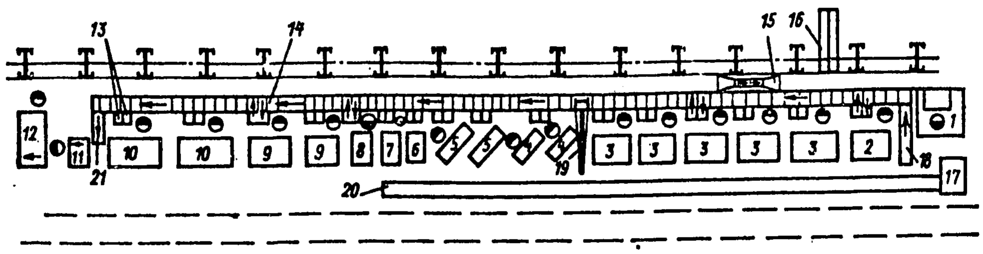

Fig. Arrangement of a specialized section for machining various types of shafts:

1. control panel
2. MR-73M milling-centering semiautomatic machine
3. Model 16K20F3 turning machine tools with ChPU
4. Model 1K62 turning machine tools
5. Model 5350B slot-cutter semiautomatic machine
6. Model 692M keyway milling machine tool
7. Model 6M82G horizontal milling machine tool
8. Model 6M13P vertical milling machine tool
9. Model 3B161 circular grinding machine tools
10. Model 3451A slot grinding machine tools
11. Model 030696A washing machine
12. monitoring plate
13. roller conveyor for receiving and issuing crates with parts to working positions
14. mechanized warehouse
15. stock-piling machine
16. roller conveyor for carrying parts to thermal treatment
17. bin for gathering cuttings
18. mobile cantilever 150kg crane
19.- 21. roller conveyors respectively for receiving crates with intermediate products and issuing crates with finished parts
20. double worm conveyor for removing cuttings

Models 6M82G, Gm13P and 3B161 will be changed to machine tools with ChPU; arrows indicate the directions of travel of intermediate products and semifinished products.

The parts are placed on the machine tools by mobile-cantilever cranes mounted on the shelving of the warehouse system. Control of all mechanisms of the warehouse-transportation system is centralized and is done by one operator from a stationary control panel. Shaft machining on this section produces considerable economic effect. A section is being prepared at the plant using the same principle to machine bushings, flanges and rings up to 300mm in diameter.

The plant has a section for housing parts, housings for milling headstocks, gear boxes, etc. which contains three multiple-tool machine tools and two drilling machine tools with ChPU. On the future, it is planned to equip this section fully with machine tools with programmed control.

An ASK-30 machining complex complex controlled by a minicomputer is being created for machining basic parts of vertical-milling machine tools with cross tables (frame, carriages, tables and stands). It will include multiple-tool machine tools (plano-milling and horizontal-boring machine tools) and an automated warehouse-transportation system. The parts are placed on satellites for machining. The heaviest machined part is five tons. It is expected that the introduction of the indicated complex will increase labor productivity by 2.5 to 3 times.

The basic parts of plano-milling machine tools with a table width of 1250 to 5000mm aremachined on combined plano-machining machine tools with a set of superposed units. This makes it possible to provide a maximum volume possible of machining in one setting. Thus, milling, planing, grinding, reaming and drilling of a part with five sides in one setting on a model UF0747 plano-machining machine tool with a 4000 x 16,000mm table is possible.

The USPO is used widely in machining and in monitoring-measuring operations, which reduces the manufacturing time of special one-time fixtures to a fifth or sixth of that used in manufacturing single-unit machine tools. Up to 8500 USPO assemblies are used at the plant during a year.

The basic trend in developing the technology of assembly work is specializing working positions and equipping them with mechanized tools adpated for group technology and test stands. The assembly work at the Ul'yanovsk Plant of Heavy and Special Design Machine Tools is divided into unit assembly and the general installation of the machine tool. The costs of fitting and finishing off are epsecially high for single unit and small series production. Therefore, a reduction in these costs (by increasing the accuracy of machining parts in the machine shops) is the basic way to improve the quality of assembly work. For this purpose, USPO, machine tools with ChPU and machine tools for finish machining of guides and planes are used at the plant.

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Improved Terminal Cutters

Moscow STANKI I INSTRUMENT in Russian No 2, Feb80 pp 28-29

[Article by G.M. Sergeev, G.A. Ginzburg: "Improvement of the Final Milling for the Processing of Spatially-Complex Surfaces"]

[Text] The use of terminal tracer-copying cutters shows that for final milling with small tolerances, the working feed along the cutter trajectory rarely exceeds 200 to 315mm/min, which does not permit full utilization of the productivity of the new tracer-copying milling machine tools and machine tools with ChPU models 6B443G, 6B444G, 6B443GF3, etc. Moreover, the necessary accuracy is not achieved in sharpening the cutting part of the cutter blade along the radius and the conjugated edge; the consumption of the cutting material is considerable, and the amount of labor in manufacturing the cutters is high.

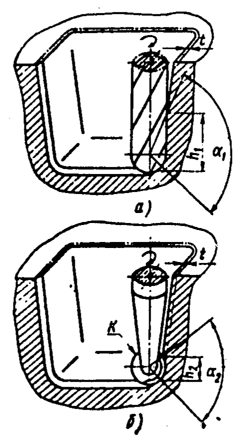

Fig. 1. Arrangement of volumetric parallel-series machining of the surface with the existing (a) and the improved (b) tracer-copying cutters.

In volumetric machining of a curvilinear surface by series-parallel passes (short lines), at the start of removal of the cutter from the cavity being machined, the length h_1 of the cutting (Fig. 1a) and the corresponding angle α_1 between the contact of the cutter blade and the intermediate product, depending on tolerance t, increase by two to three times (i.e., resistance to cutting increases). Therefore, the working feed is selected according to the greatest length of the removed cutting which reduces machining productivity considerably.

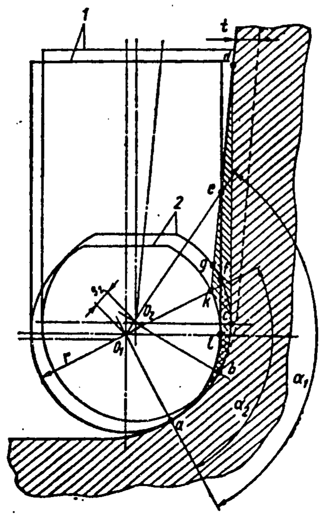

Fig. 2. Superposition of shapes of the cutting part of the existing and improved two cutters along points a, b, c, d, e, f, k, l.

In the OKBS [Experimental special design bureau] (Leningrad) the design of tracer-copying cutters for finish cutting was improved. Their cutting part was shortened (preserving the former value of the cutter overhang) and has reverse face-cutting blades K (Fig. 1b). This makes it possible to maintain constant and minimal length h_2 of the cutting and angle α_2 between the contact of the blade of the cutter and the machined part and, therefore, to increase the working feed by two to three times in series-parallel machining of the surface of any shape.

If the shapes (Fig. 2) of the cutting part of the existing one and the improved two cutters that have the same radius r of the cutting blades, are superimposed, then when the cutter centers move from point 0_1 to point 0_2 by feed value of s_z, the cross sections of the cutting for tolerance t and central angles α_1 and α_2 will be different: area acdela (bounded by two arcs and three straight line segments) is formed by machining with cutter 1 and area agka (bounded by two arcs andone straight line segment) --by machining with cutter 2.

By taking away the common part obtained by superimposing the shapes of the cross section of the cutting removed by cutters 1 and 2, it may be easily seen that its remaining part is considerably greater (more than three times) than that removed by the first cutter. At a larger cross section area, the length of the cutting and angle between the blade of the cutter and the machined part increases, i.e., the resistance to cutting increases.

For a conical cutter, the difference in the cross section area of the removed cutting may be still greater. The cross section area of the cutting removed by the improved cutter is constant in all directions of cutting (under the condition that the tolerance is uniform), which makes it possible to use the greatest working feed which is equal over the entire trajectory of the cutter.

The developed cutters may be of various shapes, integral or assembled. The latter have a mechanically attached or grazed cutting plate.

The accuracy of volumetric machining of surfaces, besides errors of the machine tool itself, is affected considerably by geometrical errors in grinding the face blades of the cutter along the radius and conjunctions with side blades. The errors are usually 0.05 to 0.1mm in grinding in special fixtures and 0.5mm and more when grinding manually with templates.

In assembled cutters, the mechanically held round-shaped plate has its rear surface ground on a circular grinding machine tool on centers in a mandrel, which reduces the error in the shape of the blade to 3-10 micrometers. Grinding a brazed cutting plate is distinguished by higher accuracy due to the absence of the conjugated edge of the face and side blades (the face blades change over directly along the radius to reverse face cutting blades).

In manufacturing new cutters, eight to ten times less cutting material is used, labor is reduced to about one-seventh and consumption of abrasive material in grinding the tool is reduced considerably.

Tests were made on an assembled cutter with a 16mm radius when machining on a model 6B443GF3 milling machine tool with ChPU 150mm in diameter samples (machining tolerance 1mm, feeds 100 and 1000mm/min). To reduce the influence of the SPID [expansion unknown] system deformation on the geometrical accuracy of the samples, they were manufactured of the AL10V aluminum alloy. Tests have shown that the geometrical accuracy (out of round) of the sample, after series-aparallel machining with the improved cutter, increased 3 to 4.5 times compared to the accuracy of machining with the usual cutter. Deviations from roundness, related to grinding the cutting blades on the face of the cutter, were not observed.

Integral and assembled cutters with brazed cutting blades may be recommended for machining forged dies and steel molds on tracer-copying machine tools and milling machine tools with ChPU, and assembled cutters with mechanically held cutting plates -- for machining cast iron drawing dies (requiring higher accuracy of the tool), as well as complicated parts of light metals and nonferrous alloys.

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CSO: 1821

METALWORKING EQUIPMENT

PROSPECTS FOR DEVELOPING HYDRAULIC DRIVE, HYDROPNEUMATIC MACHINERY

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[Article by D.I. Polyakov, deputy minister of the machine tool building and toolmaking industry: "Status and Prospects for the Development of the Production of Hydraulic Drives and Hydropneumatic Equipment for General Machine Building Applications"]

[Text] The "Main Guidelines for the Development of the USSR National Economy for 1976-80" accepted by the 25th CPSU Congress call for a considerable improvement in the quality of manufactured products, an increase in production efficiency and the development at an accelerated pace of the specialized production of products for general machine building applications.

At the November 1978 Plenum of the CPSU Central Committee, in Comrade L.I. Brezhnev's address it was emphasized that "from the beginning of the 80's it will be necessary to place even greater emphasis on intensive factors of economic growth, since other factors have been drastically shrinking. This relates primarily to opportunities for involving new labor resources." Hence it follows that a key trend in development of machine building for the forthcoming period will be the creation of machines, complexes and systems of equipment which will provide high production efficiency in the national economy with a limited need for human resources, which is being achieved by the high degree of mechanization and automation of this equipment and of production processes as a whole.

The CPSU Central Committee and USSR Council of Ministers have accepted the decree "On the Further Development of Machine Building in 1978-80," in which it is noted that during the Ninth Five-Year Plan period the output of machine building products increased more than 1.6-fold. In the Ninth Five-Year Plan period was sped up the pace of the creation and mastery of progressive types of machines, equipment and instruments, which was conducive to an improvement in labor productivity and production efficiency in industries of the national economy. In addition, it was emphasized in the decree that the production capacities reached and the technical level of some kinds of machines, equipment and instruments still do not completely satisfy the requirements for further development of the national economy.

For purposes of eliminating the present shortcomings, the CPSU Central Committee and the USSR Council of Ministers have defined the most important objectives confronting machine building ministries. One of the aspects of development of the domestic machine building industry consists in increasing the total production of and improving the technical level and quality of hydraulic drives and hydropneumatic equipment. The employment of hydraulic drives is of great importance for technical progress in many machine building industries, since it is conducive to an improvement in labor productivity and a reduction in metal content, and also makes it possible to eliminate manual labor by the introduction of automatically functioning machines and complexes. Therefore the efficiency of many modern machines is determined to a considerable extent by the degree to which they are furnished with hydraulic equipment.

In recent decades the hydraulic drive and hydropneumatic automatic equipment have become widespread, especially in machine tool and press building. These industries are traditional users of different kinds of pneumatic equipment and here has been observed a tendency toward further broadening of the range of application of this equipment. A number of machines which previously had an electromechanical drive have been converted to a hydraulic drive, which has drastically increased the level of automation. In some machines performance of the working process is totally impossible without a hydraulic drive (for example, in presses for the production of superhard synthetic materials and for stamping with an elastic medium, in hydrostats and some others).

The use of a hydraulic drive for the main drive in tractors makes it possible to increase by 30 percent labor productivity in ploughing and the productivity of grain harvesting combines with a hydraulic drive by 40 percent, to reduce the metal content of drilling rigs and to increase their productivity by 35 percent, and to increase drastically the technological capabilities of road building machines and the reliability and quality of operation of many kinds of metallurgical equipment. The overwhelming majority of currently existing automatic manipulators (industrial robots) are furnished with hydraulic and pneumatic drives, which will remain the main type of drive for them in the next few years.

The same attention which in its time was paid to the electrification of the national economy should be paid at the present time to the hydraulic conversion of machines in different branches of industry.

Able to serve as a confirmation of the role which belongs to hydraulic drives in modern machine building are the high rates of growth in their production over the entire world, including in our country.

In the Minstankoprom [Ministry of the Machine Tool Building and Tool Making Industry] system in approximately 10 years has been created an essentially new subindustry for the production of hydraulic drives and hydropneumatic lubricating equipment for interindustrial use. The total output of these products at specialized enterprises has grown more than 15-fold as compared with 1967, including more than 2.6-fold in the Ninth Five-Year Plan period as compared with the Eighth. In 1980 it is planned to increase the output of these products more than 1.6-fold as compared with 1975. There has been a considerable increase in production of hydraulic equipment at enterprises of Minstroydormash [Ministry of Construction, Road and Municipal Machine Building], Minsel'khozmash [Ministry of Tractor and Agricultural Machine Building] and Minavtoprom [Ministry of the Automotive Industry].

The broadening of the range of application and the increase in the total output of hydraulic drives has been accompanied also by qualitative changes in their technical characteristics. Whereas previously the distinctive feature of hydraulic systems was simplicity and a low concentration of power, and their capabilities were relatively limited, a modern hydraulic drive is a combination of different complicated hydraulic mechanisms and equipment having high energy parameters, high speed of response and high accuracy in running through control signals. The broadening of the range of variation of the speeds of the working elements of machines which have been made hydraulic, associated with the increase in their performance, has made ineffective the previously widely used type of drives with throttle control and utilizing relatively simple uncontrolled pumps. The percentage of drives with dilatational control has been increasing steadily.

The heightening of the requirements for the quality of the processing of materials has made necessary the continuously variable regulation not only of the speeds of working elements and of machinery which has been made hydraulic, but also of the force developed by them, which in turn requires appropriate control of fluid flow rates and of pressure values in hydraulic systems, whereby this control should be accomplished both by means of the operator and automatically.

The technical level and quality of modern hydraulically converted machines is determined chiefly by the degree of perfection of the hydraulic equipment and by an intelligent structure for the hydraulic system. In the future is to be expected the more extensive utilization of a system for program and adaptive control of the operating cycle of machines. It has become necessary to combine them with electrical and electronic control and monitoring systems.

The technical specifications placed by users on elements of hydropneumatic equipment have been steadily increasing, which has compelled their manufacturers to improve their products constantly.

Called for is the creation of new kinds of hydropneumatic equipment responding to the main trends in the development of hydraulically converted machines operating in an automatic cycle, including industrial robots and heavy and unique equipment.

Called for is the production of controllable valve-distribution radial piston pumps developing an operating pressure of 50 to 63 MPa and having enhanced efficiency in the delivery regulation range of up to 1:10, a control speed of response on the order of 0.03 to 0.05 s, and a discharge rate of 25 to 630 liters/min.

There has been an increase in the production of unified axial piston pumps designed for a pressure of 32 MPa and a discharge rate of up to 400 liters/min, furnished with mechanisms for remote proportional control of output and the flow rate and pressure of the working fluid; there has been an increase in the production of hydraulic equipment with program control, including safety valves, throttles, flow rate regulators and hydraulic distributors.

All these advanced types of hydraulic equipment have been designed for modular assembly and have been executed in the form of slide valves or valve equipment.

There has been an increase in the production of servo slide valves for unique machines with a delivery of up to 5000 liters/min, of oil cylinders based on long-life polyurethane packings, of filters with a filtering fineness of down to 5 μ furnished with devices for electronic visual signaling regarding clogging, and of a number of other constructions.

Whereas as in the Ninth Five-Year Plan period about 720 type sizes of different hydropneumatic equipment were in production, in the 10th Five-Year Plan period, on account of expansion of the types and their mastery, is foreseen the production of more than 1000 type sizes, and in the next future period, i.e., in the 11th Five-Year Plan period, up to 1300 type sizes. Every five or six years there takes place the modernization or replacement of products produced with new more advanced ones. Suffice it to say that over the last five years has taken place the replacement of almost all major products of specialized plants of the Soyuzgidravlika VPO [All-Union Production Association] (sliding vane and axial piston pumps, hydraulic actuators, hydraulic and pneumatic control and regulation and distributing equipment, and servo slide valves), and in the process of this replacement have been achieved technical and operating parameters conforming to the level of the best models in the world. At the present time the number of products which have been in production less than five years equals about 60 percent, and less than three years, 34 percent. The percentage of products certified with the State Emblem of Quality of the total amount of commodity products has reached approximately 35 percent, and by the end of the five-year period will equal 43 to 45 percent.

Important structural changes have taken place in the area of the production of hydropneumatic equipment. As the result of the performance of a combination of scientific research and experimental design studies relating to the creation and mastery of the production of new kinds of hydraulic drives and hydropneumatic equipment, it has been possible to improve the structure of the production of these kinds of products by improving the percentage of modern advanced products. For example, the total production of elements of hydropneumatic equipment for outfitting automatic machine tools and presses and machines with program control has increased 2.5-fold as compared with 1975, and for outfitting heavy and unique equipment, 3.4-fold. There has been a twofold increase in the production of hydraulic and pneumatic equipment for pipeless methods of assembly with international connecting dimensions; the production has been mastered, of controllable valve-distribution axial piston pumps distinguished by a high speed of response for the control process and enhanced efficiency with a fairly wide range of variation in discharge (1:7), capable of longterm operation at a pressure of up to 40 MPa; the manufacture of automatic lubrication systems has also been mastered. The operating life of major types of hydraulic equipment has been increased 1.2-fold and of pneumatic equipment 2.1-fold, and the unit metal content has been reduced 1.4-fold.

The mastery has been begun of electrohydraulic equipment with proportional remote control. Whereas up to now electronics has been used chiefly for creating servomechanisms with electrohydraulic amplifiers, at the present time is being developed the production of control and regulating and distribution equipment employing proportional linear magnets and pumps with remote control of flow rate and pressure, which has created a basis for designing optimal hydraulic systems for the majority of machines converted to hydraulics. During the years of the 10th Five-Year Plan a number of scientific research studies were conducted, as the result of which interesting solutions were found. For example, a system has been created for synchronizing the movement of oil cylinders on the basis of double-flow pumps ensuring a mismatch in the position of cylinders in the range of one percent in all operating modes; a method of dilatational control has been developed with the achievement of low steady discharge (a control ratio of 1:150) with a pressure of 50 MPa and more, on the basis of which have been created hydraulic drives for sheet metal bending presses, presses for cold extrusion of embossed recesses, and machine tools for making sharp bends in large pipes made of alloy steel.

A method has been developed along with a set of algorithms and programs for the standard-unit designing and functional technical diagnosis of pneumatic, pneumohydraulic and electropneumatic digital systems for controlling machine tools, industrial robots and other automatic machines. This method makes it possible to arrive at a system of minimized logic equations according to which the design of the control system is carried out, and it gives a description of the system in the form of a list of inputs and outputs of logic elements (distributors and valves) in keeping with the marking of their channels employed in international practice. Studies have been developed relating to the employment of mathematical methods of analyzing and synthesizing hydraulic equipment and to their optimization, enabling the achievement of assigned parameters. General-purpose programs have been created for the optimization of individual kinds of hydraulic equipment containing the logic of the method of seeking optimal solutions, which can be used for a rather wide range of problems.

However, much still needs to be done in order for the production of hydropneumatic equipment and also its technical level to conform to contemporary and future requirements. There is a scarcity of individual kinds of hydropneumatic equipment, and although the rates of growth in the production of hydraulic devices and hydropneumatic equipment will remain very high, the demand for them by different machine building industries is growing all the more rapidly. It is planned to satisfy part of this demand by deliveries from CEMA member countries which are developing the production of these products on the basis of socialist integration, specialization and cooperation. These deliveries have been increased substantially in the current five-year plan period and a further growth in them has been proposed for the forthcoming period.

For the purpose of reducing the present inconsistency between the production of hydropneumatic equipment and the demand for it, it is necessary to organize the development of the specialized production of this equipment. Minstankoprom together with other machine building ministries will carry out the organization of the performance of scientific research and experimental design work relating to the creation and introduction into production of new kinds of hydraulic drives and hydropneumatic equipment, to the improvement and unification of technological processes, and also to the organization of the centralized production of these products and the improvement of the specialization of existing enterprises and shops making hydropneumatic equipment.

In connection with the fact that a considerable portion of hydraulic equipment parts have common design and technological features, a solution to the problem of a further growth in total production should be sought along the line of creating large enterprises on the principles of specialization in terms of parts or assemblies with the employment of an advanced technology for mass production and of modern forms and methods of labor organization.

A further increase in the technical level and quality of hydraulically converted machines is possible only with an overall approach to solving the problem, covering both problems relating to the creation of new kinds of hydraulic equipment with the characteristics required, to improving manufacturing quality and to achieving an optimal nomenclature for the element base for hydraulic drives, and questions relating to furnishing them with the appropriate outfitting items, materials and working fluids, as well as questions relating to the optimization and standardization of hydraulic systems ensuring the reliable and efficient functioning of drives.

The efforts undertaken by organizations and enterprises creating and mastering new kinds of hydraulic equipment or improving already manufactured products will prove to be insufficiently effective if concomitantly with them are not solved questions relating to the production of high-quality packings, modern electromagnets, working fluids, standardized and precision pipes, high-pressure hoses and the like.

Statistics testify to the fact that the failure of packings and unsatisfactory condition of the working fluid are the reason for the failure of hydraulic systems in 60 percent of cases. An analysis of the quality of packings manufactured by Minneftekhimprom's [Ministry of the Petroleum Refining and Petrochemical Industry] rubber engineering component plants has shown considerable deviations in these components from modern requirements, which has had a negative effect on product quality. In the area of packing equipment, studies on the creation of modern packings are insufficiently coordinated, and this has resulted in the fact that enterprises of many ministries and departments are involved in developing and making them. The level of packing equipment does not always respond to the objectives of developing the production of hydraulic drives. For high-pressure hydraulic systems are required packings of improved quality made of polymer and composite materials which have the required use characteristics.

An important condition for the efficiency of hydraulic equipment is the quality of working fluids used.

In spite of, it would appear, the large nomenclature of forms of petroleum, modern hydraulic drives, especially high-pressure, do not have the necessary working fluid with the required combination of additives ensuring the reliable operation of elements of hydraulic equipment and maintaining the use properties of the fluid for a sufficiently long time, on the order of 10,000 hours.

In international practice a classification is used for working fluids based on petroleum, according to which they are subdivided into three main groups: fluids without additives, with a limited number of additives, and with a complete combination of additives. Different fluids, even those belonging to a single group, behave differently under actual conditions of the operation of a hydraulic drive, and the use of the improper fluid can result in units of the drive quickly going out of order. For the operation of hydraulic equipment under conditions of high pressures, speeds and temperatures, it is necessary to use only so-called wear-resisting oils having an improved ability to protect from corrosion and oxidation, heat resistance, resistance to the formation of deposits, and a good ability to be pumped through filters.

The lack among us of such a classification and of distinct recommendations for the use of different fluids for machine building hydraulics has resulted in the fact that in use hydraulic drives are often filled with arbitrary fluids which do not conform to the technical specifications for a given drive. This has resulted in a drastic reduction in the reliability of machines.

Hitherto production has not been organized for modern electromagnets with a "wet" armature and of proportional magnets based on them which at the present time can be widely used as control devices for different hydraulic apparatus.

The lack of the production and delivery of precision pipes produced by methods of plastic deformation has been retarding the growth of the total output of modern hydraulic and pneumatic cylinders, the demand for which by different machine building industries is exceptionally high.

Special attention should be paid to improving the technical level of production and the manufacturing quality of products. Even a relatively simple hydraulic drive consists of a dozen different elements, and in more complicated ones this number is increased severalfold; therefore, it becomes obvious that even in spite of the high quality of the overwhelming number of components, the entire hydraulic drive can prove to be ineffective because of a single non-high-quality item included in its design.

Precision in the manufacture of major parts is of great importance. A high degree of precision not only makes possible the interchangeability of parts, but also guarantees the appropriate quality of operation of equipment. Therefore, improving the manufacturing precision of hydraulic equipment parts is a quite urgent problem which can be solved by improving the structure of the inventory of metalworking equipment by increasing the percentage of special machine tools, automatic machine tools and equipment with program control guaranteeing steadiness of quality in the production process.

Great attention must be paid to questions relating to further improving the technical level of production and manufacturing quality, as well as to problems of more fully satisfying the demand for hydropneumatic equipment products. The program for developing the production of and improving products must provide for the further improvement and perfection of products manufactured by specialized enterprises.

Special attention must be paid to the creation of a complex of hydropneumatic equipment making possible the production of metalworking and woodworking equipment and other machines operating under conditions of automated production processes, to improving quality, and to developing an element base, primarily by the creation of control and regulation and distributing equipment and of actuating systems with feedback equipment ensuring high speed, precision and reliability.

An important trend is the creation of combined automated and servo mechanisms based on the available element base and that under development and on the optimization of solutions taking into account the properties of working fluids.

For the purpose of solving the problem of more fully satisfying the demand of the national economy for hydropneumatic equipment products and for further improvement of its technical level and quality, a program has been developed for the development of the production and improvement of these products, based on the following: drafts of longterm science and engineering programs of leading industrial institutes; a longterm special-purpose program for cooperation with regard to hydropneumatic equipment within the CEMA framework; recommendations of the commission of specialists on hydraulic equipment developed under an assignment from GKNT [State Committee on Science and Technology]; an analysis of the status and development trends of studies on the creation and production of hydropneumatic equipment abroad; data on the balance between the current and future demand and the total production of these products in the USSR.

For the purpose of carrying out this program it is necessary to solve the following problems: 1) To create within the extent of the required nomenclature a complex of hydropneumatic equipment for machines operating under conditions of automated production processes, and to satisfy the demand for this equipment from enterprises of Minstankoprom and other machine building ministries. 2) To improve the quality indicators of standard hydropneumatic equipment with regard to all equipment operation parameters for the purpose of achieving the highest level ensuring its effective employment in production for the longest time possible. 3) To improve the technical level of production for the purpose of ensuring steady quality in the manufacture of products.

In the process of solving these problems the following is called for: further development of the element base with respect to nomenclature, primarily by creating new kinds of delivery equipment (variable vane pumps for a pressure of 16 MPa, piston pumps with an operating life of 10,000 to 14,000 hours for a pressure of up to 50 MPa), furnished with remote mechanisms for controlling delivery and pressure, and equipment of different designs with automatic regulation and the ability to perform complex functions, designed for operation in program and adaptive control systems, and actuators with velocity and position feedback devices, etc.; the creation of complete automated drives based on the present element base and that under development, as well as the optimization of the design of hydraulic drive systems, taking into account the properties of working fluids; the introduction of a standard-unit method of designing and manufacturing hydraulic systems for the entire series of machines, based on finding standard structural configurations and creating unified functional blocks; improving the technical parameters of hydropneumatic equipment and reducing overall and hydromechanical losses in systems by improving the analytical fundamentals of designing, by expanding advanced methods of assembly, by using high-strength and wear-resistant materials and methods of hardening by chemical and heat treatment, as well as by using improved types of outfitting items; reducing the level of noise and vibrations in the operation of hydraulic equipment by introducing active and passive methods of suppressing them; and by ensuring the use in systems of machines operating under fire hazard conditions which employ noncombustible fluids, and modified hydraulic equipment unified with items for general machine building applications.

The completion of this program requires the intensification of scientific research and of theoretical substantiation, the extent of which must be increased considerably.

Enterprises and organizations of ministries supplying outfitting products for hydropneumatic equipment must make their contribution to solving the problem of developing the production of hydraulic drives.

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METALWORKING EQUIPMENT

POTENTIAL FOR MACHINE BUILDING ENTERPRISES IN SIBERIA

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[Article by Candidate in Economic Sciences A.I. Shrago: "Scientific and Technical Potential of Machine Building Enterprises in Siberia"]

[Text] In the "Main Guidelines for the Development of the USSR National Economy for 1976-80" are called for a further growth in the economic potential of the eastern regions and an increase in their role in the public production of industrial products, along with the speedier development of industries having the most favorable prerequisites for this, especially the fuel industry and energy intensive production processes.

An important feature of the speedy development of the productive forces of Siberia is the fact that the major increase in its production potential will be realized on account of the northern regions, with more severe climatic and special geological and mining conditions. Furthermore, Siberia cannot be counted on in the future for a substantial increase in labor resources. Consequently, the solution to the problem of developing the productive forces of Siberia lies in utilizing the achievements of scientific and technical progress and in improving the equipment ratio. Furthermore, important for this region are a radical change in production technology and the mechanization and automation of labor and the creation of designs of machines, gear and equipment capable, without a reduction in performance, of operating at any time of the year under conditions of the severe Siberian climate.

Of course, the effectiveness of the employment in Siberia of equipment designed for the European sector of the country is two to three times lower than in regions with a moderate climate. For example, the service life of tractors prior to a major overhaul is reduced from 5000 to 2500 hours. The performance of excavators, even in southern regions of Siberia, is reduced 25 to 30 percent in the winter months. The service life of motor vehicles when operating under northern conditions is reduced 50 percent. Mining combines and complexes adapted to the mining and geological conditions of the Donets Coal Basin cannot operate in the Kuznetsk Basin. Siberia's lumber industry requires more powerful machinery as compared with that used in the country's European sector. From this it follows that a necessary condition for the speedier development and mastery of new regions of Siberia is the development of this region's machine building complex.

During the years of the Soviet regime and in particular in the postwar period in Siberia have been created machine building enterprises with advanced equipment which produce machines and equipment at the level of the best domestic and world standards, such as Sibelektrotyazhmash, Tyazhstankogidropress, Sibtyazhmash, the Krasnoyarsk Combine and the Altay Tractor.

Together with this, in Siberia's machine building industry there are considerable disadvantages and disproportions which have considerably reduced its role in the overall development of the economy of Siberia and other eastern regions of the RSFSR. For example, the percentage of Siberia's gross product of the USSR gross product in 1978 equaled about 10 percent, and the percentage of machine building products less than eight percent of all-Union production.

In Siberia has been formed a concentration of five machine building industries--power, electrical, mining, machine tool building, tractor and agricultural; to the share of these industries belongs about 50 percent of all machine building and metalworking products. About 70 percent of these products are shipped beyond the limits of Siberia and the Far East. In the shaft mining and ore mining machine building industry are produced basically structurally uncomplicated machines and equipment (conveyers, cars, winches, ventilators, drilling rigs and hydraulic excavators) and stoping and tunneling combines and loading machines and complexes and other equipment are shipped.

Insufficiently developed or absent are important machine building industries which are exceptionally important for the development of Siberia, such as road building, underground transportation and motor vehicle building, and machinery for the oil and gas industry is being produced inadequately.

The machine building industry of the eastern regions was formed to a considerable extent and continues to be developed not according to the economic laws of distribution; therefore, it is poorly adapted to the needs of these regions. In our opinion, it is necessary to develop Siberia's machine building industry along the lines of speeding the industry's rate of development, of bringing the structure of production closer to the structure of consumption, and of creating complexes of machines and equipment adapted to the climatic and geological and mining conditions of Siberia. For the purpose of accomplishing these objectives, Siberia's machine building industry must have available a strong scientific and technical potential capable of creating in a short time the new advanced equipment needed by Siberia's economy.

Under modern conditions scientific and technical progress represents a unified process of carrying out scientific research and planning and design developments and the introduction on a wide scale of new highly efficient tools and articles of labor and of an improved technology and methods for production control. All this should ensure an increase in product output and improvement of its quality and a more efficient utilization of all types of production resources for purposes of the intensification of production and increasing its efficiency.

The extensive introduction of scientific achievements in all areas of the national economy has heightened the dependence of production on the level of development of science.

The process of scientific research and the practical introduction of its results into production consists of three interrelated cycles: basic research, applied research and scientific research and experimental design developments (NIOKR's).

The exact proportions between the extents of the various cycles depend on the state of the art of the specific branch of knowledge, technical progress and other factors. However, in all cases of first-level importance in the development of scientific and technical progress and in the introduction of its results into production are NIOKR's.

One of the practical problems in the development of scientific and technical progress consists in the proper intelligent distribution of expenditures between basic and applied research and development, of the total amount of capital allotted for these purposes. From statistical data on the cost of different kinds of scientific research in many countries of the world has been gotten the following ratio defining the mean level of expenditures for each cycle: 1:3:6.

According to one set of data, in our country 12.7 to 12.9 percent of the money spent on science is consumed for basic research, approximately 60 percent for applied research, and 26.6 to 27.3 percent for development; according to another set of data this ratio equals 14:22:64, and in the USA it equals 12:23:65. In all cases the total expenditures for scientific research and experimental design development make up the major percentage of all allotments.

In connection with the creation in Siberia of a division of the USSR Academy of Sciences, basic research has been given considerable development; to Siberia's share belongs 10 percent of the amount of basic scientific research in the country, but Siberia's share in developments of an industrial nature and in planning and experimental design work is only three to five percent.

A special role in speeding the introduction of the achievements of academic and industrial science into the national economy belongs to machine building with its scientific and technical potential (NTP).

Among investigators there is no unified opinion regarding the content and system of indicators by means of which it would be possible to determine the level of development of the scientific and technical potential of an enterprise.

In our opinion, by the NTP is meant the degree of saturation of an enterprise with engineering and technical personnel and the level of development of plant subdivisions such as central plant research laboratories (TsZL's); special (separate) design bureaus (SKB's and OKB's); chief designer, chief technologist, metallurgist and welder divisions; mechanization and automation divisions; testing and experimentation subdivisions; as well as scientific research, planning and design and planning and technology institutes at the plant or near it.

Able to serve as an acceptable indicator (PP) of the development of the scientific and technical potential of an enterprise is the arithmetic mean of the following factors: K_1--the degree of saturation of an enterprise with ITR [engineering and technical personnel]; K_2--the degree of saturation of an enterprise with personnel working in laboratories and design, technological and experimentation subdivisions; K_3--the degree of saturation of laboratories and design, technological and experimentation subdivisions with ITR; and K_4--the degree of saturation of an enterprise with designers and technologists.

With the existence at an enterprise of an NII [scientific research institute] (KB's [design bureaus] and OKB's), in the first three indicators it is necessary to take into account as an independent balance both all NII (KB and OKB) personnel and ITR, and in the fourth indicator must be taken into account only the enterprise's designers and technologists. The factors of an enterprise's potential can be determined from the following equations:

$$K_1=\frac{I_p+I_i}{A_p+A_i};\quad K_2=\frac{A_1+A_i}{A_p+A_i};$$
$$K_3=\frac{I_i+I_i}{A_p+A_i};\quad K_4=\frac{K+T}{A_p};$$
$$PP=\frac{K_1+K_2+K_3+K_4}{4},$$

where I_p is the number of ITR at the enterprise; I_i is the number of NII (KB or OKB) ITR; A_p is the number of industrial production personnel at the enterprise; A_i is the number of industrial production personnel in KB's and OKB's; A_1 is the number working in laboratories and design, technological and experimentation subdivisions of the enterprise; I_1 is the number of ITR in laboratories and design, technological and experimentation subdivisions of the enterprise; and K and T are the number of designers and technologists.

The degree of development of the NTP of an enterprise and the values of factors depend on the machine building subindustry, the type of production and the scale of production (the number of workers).

At enterprises of advanced machine building industries (instrument making, computer technology, power and electrical machine building, etc.), the saturation factors should be higher than in other industries, while in mass and large-lot production they should be lower than in single-unit and small-lot production. In plants with the same type of production, the saturation factors should be higher at medium enterprises (3000 to 7000 workers) than at large ones (15,000 and more workers). In table 1 are given the saturation factors and the level of development of the scientific and technical potential of a number of machine building plants in Siberia. These factors have been calculated from data on enterprises for 1975.

Table 1.

Name of enterprise	Type of production	K_1	K_2	K_3	K_4	PP
Sibelektrotyazhmash	Single-unit, small-lot	0.270	0.162	0.108	0.124	0.166
Kuzbasselektromotor	Series	0.186	0.110	0.061	0.093	0.112
Kemerovo Electrical Equipment	Series	0.115	0.049	0.031	0.038	0.058
Sibtyazhmash	Single-unit, small-lot	0.252	0.130	0.100	0.153	0.163
Barnaul Boiler Plant	Single-unit, small-lot	0.220	0.037	0.030	0.120	0.095
Kuznetsk Machine Building Plant	Series	0.166	0.091	0.058	0.079	0.098
"Trud" [Labor] Plant	Single-unit, small-lot	0.170	0.061	0.041	0.076	0.086
Anzhero-Sudzhensk Machine Building Plant	Series	0.140	0.045	0.027	0.050	0.065
Novosibirsk Tyazhstankogidropress Plant imeni Yefremov	Single-unit, small-lot	0.262	0.143	0.106	0.150	0.165
Novosibirsk Machine Tool Building Plant imeni the 16th Party Congress	Small-lot	0.215	0.070	0.051	0.087	0.105

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Krasnoyarsk Production Association for Grain Harvesting Combines	Mass	0.150	0.049	0.031	0.063	0.073
Altay Tractor Association	Mass	0.150	0.070	0.042	0.063	0.081

The analysis conducted makes it possible to divide into three groups all machine building enterprises in relation to development of scientific and technical potential. Under the first group can be placed enterprises (associations) having an advanced experimentation and laboratory base, advanced technological subdivisions (chief technologist, metallurgist and welder divisions and divisions for designing rigging and tools), and a chief designer's division. At these enterprises or near them there is a scientific research institute or a special (separate) design bureau. These plants conduct research and development and master and introduce new equipment, often not only for their own enterprise but also for other plants of the industry. Under these enterprises it is possible to classify, for example, Sibelektrotyazhmash, Sibtyazhmash, the Novosibirsk Tyazhstankogidropress Plant imeni Yefremov, the Altay Tractor Association and Kuzbasselektromotor.

Among the second group must be placed plants (associations) which have a traditional but sufficiently developed laboratory base and technological and design subdivisions and a small experimentation shop or section. These enterprises together with the mastery and introduction of designs of other organizations are involved in the modernization and development of in-plant designs. Among these enterprises can be classified the Barnaul Boiler Plant, the Novosibirsk Machine Tool Building Plant imeni the 16th Party Congress, the Krasnoyarsk Production Association for Grain Harvesting Combines, and the Kuznetsk Machine Building Plant.

Among the third group are classified plants which do not develop and almost do not master new equipment. At these enterprises are small in-plant laboratories and technological and design subdivisions which routinely serve production and introduce previously mastered (at other enterprises) products. In terms of size these are small enterprises with 1000 to 4000 workers.

The level of the development of the scientific and technical potential of enterprises (the value of the PP factor) for each group of enterprises depending on the type of production and size is given in table 2.

These factors can be corrected, but even in this form they can serve as a criterion for comparing and rating the level of the scientific and technical potential of an enterprise.

Table 2.

Enterprise group	Level of scientific and technical potential (PP factors)			
	Enterprises with single-unit and small-lot production		Enterprises with series and mass production	
	Large	Medium	Large	Medium
I	>0.12	>0.15	>0.08	>0.11
II	0.08 to 0.12	0.11 to 0.15	0.05 to 0.08	0.08 to 0.11
III	-	<0.11		<0.08

In Siberia's machine building and metalworking industry under the heading of the first group of enterprises can be placed only five to eight percent of the total, of the second group 10 to 12 percent and of the third 80 to 85 percent. The scientific and technical potential of the majority of Siberia's machine building enterprises is weaker than that of similar enterprises in the European sector of the USSR. For example, the Anzhero-Sudzhensk Machine Building Plant, the Kiselevsk Machine Building Plant imeni Chernykh and the Prokop'yevsk Mining Automatic Equipment Plant are similar in terms of the purpose of products produced, the type of production and the number of industrial personnel to the Dnepropetrovsk Shaft Mining Equipment Plant and the Voronezh Ore Concentration Equipment Plant. But the percentage of ITR of the total number of industrial personnel (factor K_1) at Siberian plants equals 0.14 to 0.17, and 0.18 to 0.195 at European. The personnel figure for scientific personnel and ITR working in laboratories and design and experimentation subdivisions (factor K_3) equals 0.025 for the machine building and metalworking enterprises of Altayskiy Kray, and 0.019 of Kemerovskaya Oblast, and in the European sector of the USSR this figure is close to 0.05 to 0.06 [2].

In Siberia, as a region being developed with relatively limited labor resources, it is important to achieve high economic indicators for the development of the national economy on the basis of scientific and technical progress, which is inseparable from the development of machine building. Siberia's machine building complex must become not only a center for the production of the latest equipment, but also a center for the creation of new designs. This is especially important for machines, gear and equipment operating under the specific conditions of the region.

Thus, the solution of the problems confronting Siberia's machine building industry requires a considerable increase in the percentage of enterprises with a high level of development of their scientific and technical potential.

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